Fourth Annual Conference on Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

Geologic - Frio Brine Field Project (1)

From Concept to Reality: A systematic management approach for field implementation of the Frio Brine Pilot Test

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May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia

Shout Out to Co-authors

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- Susan D. Hovorka - Texas Bureau of Economic Geology
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- Larry R. Meyer - Lawrence Berkeley National laboratory

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- Alberta Research Council: Bill Gunter, John Robinson
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- Sandia Technologies: Dan Collins, Edward "Spud" Miller, David Freeman; Phil Papadeas
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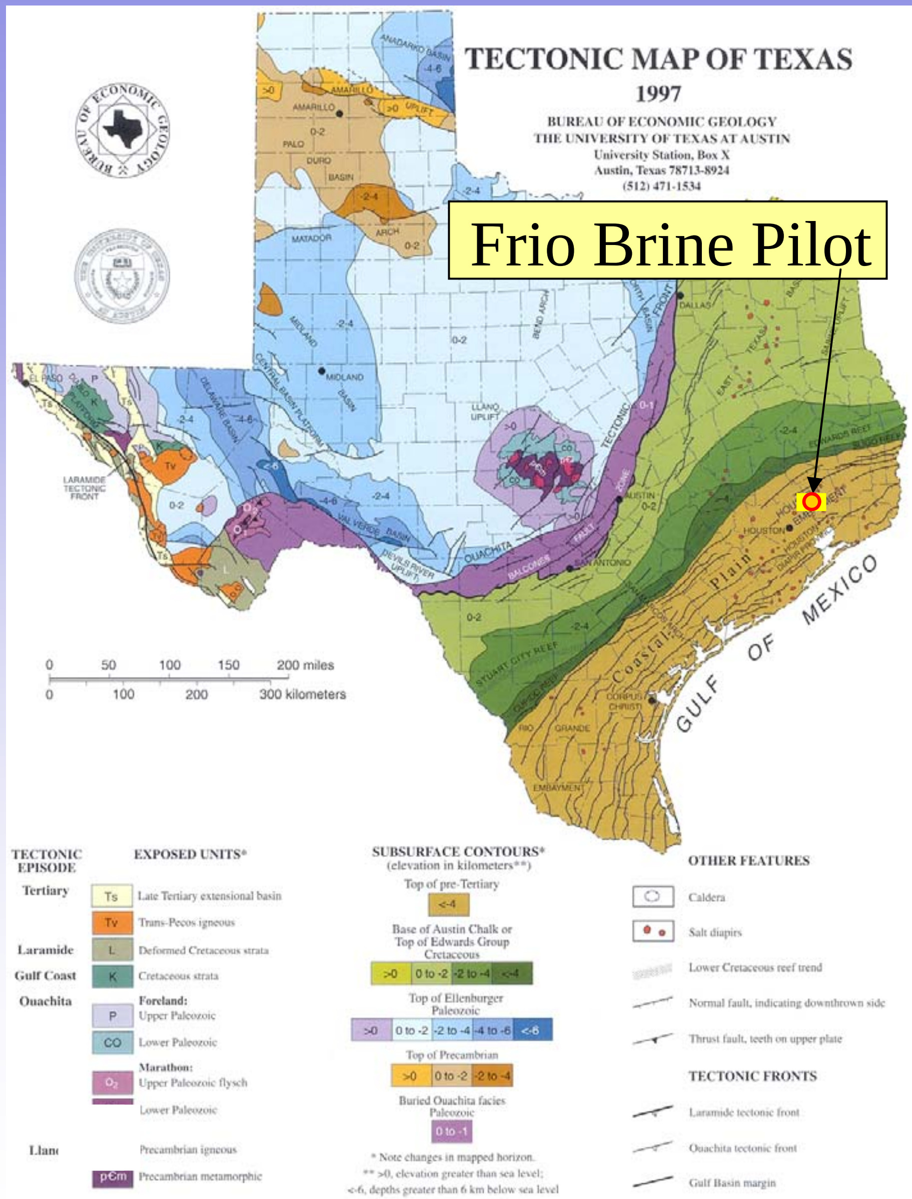
- Schlumberger: T. S. Ramakrishna, Austin Boyd, Nadia Muller, Pokey Mangum, and others
- SEQUIRE – National Energy Technology Lab: Curt White, Rod Diehl, Grant Bromhall, Brian Stratizar, Art Wells
- University of West Virginia: Henry Rausch
- USGS: Yousif Kharaka, Bill Evans, Evangelos Kakauros, Jim Thorsen
- Praxair: Joe Shine, Dan Dalton
- Australian CO_2CRC (CSRIO): Kevin Dodds and Don Sherlock
- Core Labs: Paul Martin, Russ Peacher, and others

Project Location for Frio Brine Pilot

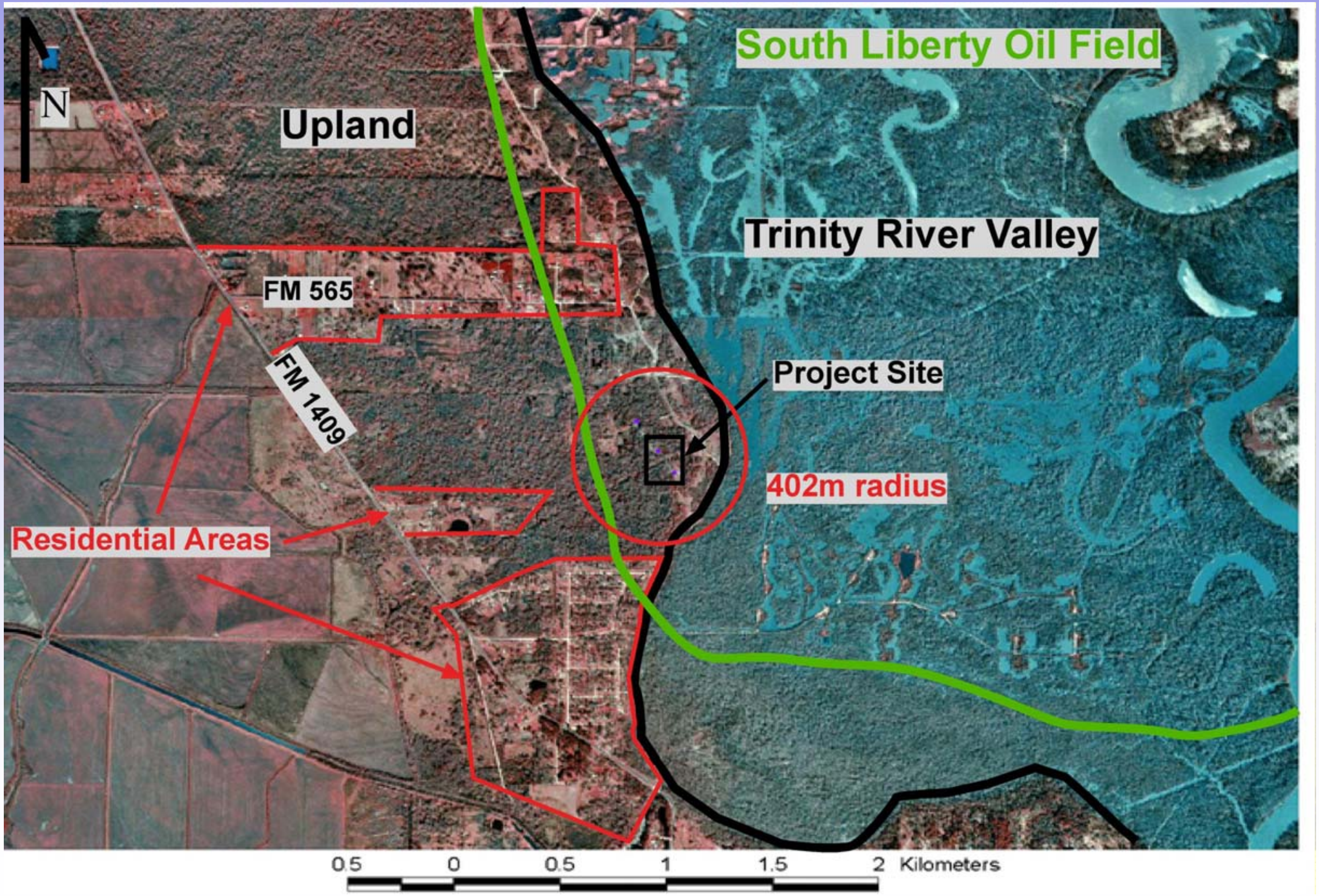


Test site is located on the southwestern flank of Dayton Dome along the Upper Texas Gulf Coast

Dayton Dome is a salt piercement structure located within the Houston Embayment

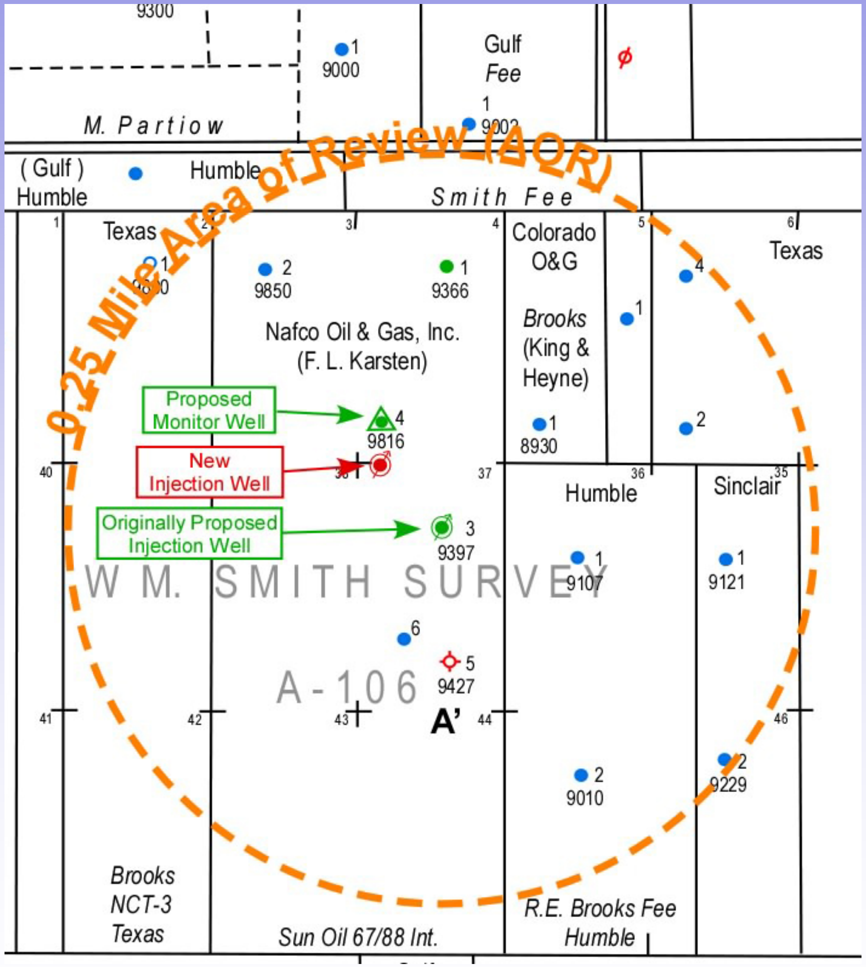
The Injection and Observation Wells are located within a common fault block, bounded by faults to the southeast and northwest and the dome to the northeast

Frio Brine Pilot - Detailed Site Setting

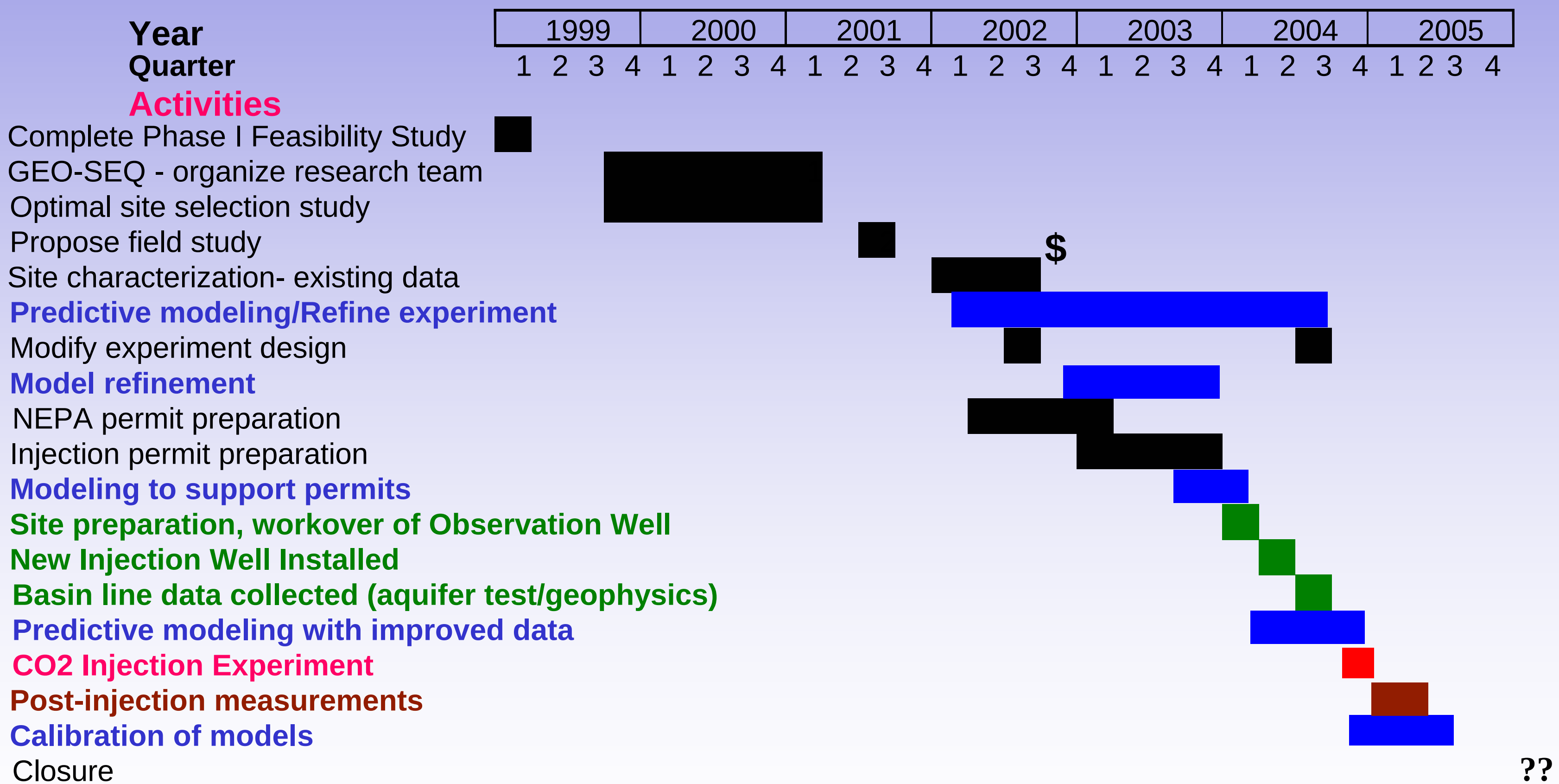


Frio Brine Pilot - Site Area

- All of the nearby productive wells are from the Yegua Formation at +/- 8,800
- Tract is a 60 acre lease
- Lease Wells 1 through 5 were drilled in the 1950s, Well 6 was drilled by TARC in 1997
- Original plan was to recomplete the Sun-Gulf-Humble Fee No. 3 Well to the Injection Well, Modified plan resulted in installation of a new injection well for the Frio Brine Pilot
- Well to Well Distance ~ 100 feet



Evolution of Frio Pilot



$ = DOE funding for field activities received

Project Planning/Management Goals

- Evaluate/Screen potential measurement, monitoring & verification technologies prior to site implementation (GEO-SEQ)
- Appropriately plan and sequence science experiments to minimize "competition" for the borehole(s)
- Optimize wellbore configurations for each phase of testing and minimize well recompletions
- Obtain continuous data during CO_2 injection for scientific analysis and regulatory compliance per permit conditions

Project High Risk Elements

- Quality of Cement Integrity/Isolation in the Observation Well from the Rework/Recompletion
- Drilling/Completion Problems in the Injection Well
- Quality of Cement Integrity/Isolation in the Injection Well
- No Interwell Communication or CO_2 Breakthrough at the Observation Well
- Downhole equipment failures during CO_2 Injection
- Large CO_2 Release on Location

Optimizing the Science

- Field methodologies had to be well thought out to ensure that “interference” between competing tests would not invalidate results of one or both tests
- Experiments were potentially limited by casing restrictions and packer restrictions during CO_2 injection AND borehole “competition”

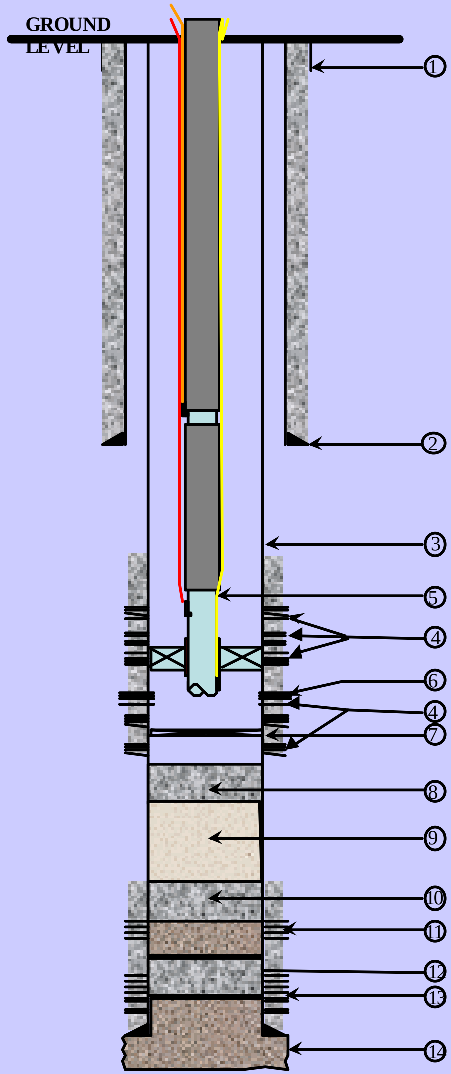
Project Safety

- All field activities were performed under a site wide Health & Safety Plan (subtasks were added as addendums to the “site wide” HASP)
- Safety was considered a “key” element in Vendor selection
- Site safety meetings were held at the beginning of each shift and prior to all “non routine” activities
- A formal Process Safety Review (PSR) was held with the CO_2 supplier and pumping vendors prior to field mobilization
- Well flow back and CO_2 injection activities were monitored with surface meters/alarms

In Place Observation Well

- Observation Well is a former oil producer from the Yegua Formation at 8,800+ feet (1950s)
- The well casing was evaluated for integrity and plugged back to the Frio Formation in 8/03
- Circulating squeezes (5 sets) were performed to isolate the upper Frio Test Interval and Anahuac Formation (overlying seal) in 5/04
- Efficacy of squeezes were demonstrated by radioactive tracer survey follow perforation of the Frio C Sand

Observation Well Recompletion Detail



All depths reference RKB

KB = 12.7' above LMCF

G.L= 65'

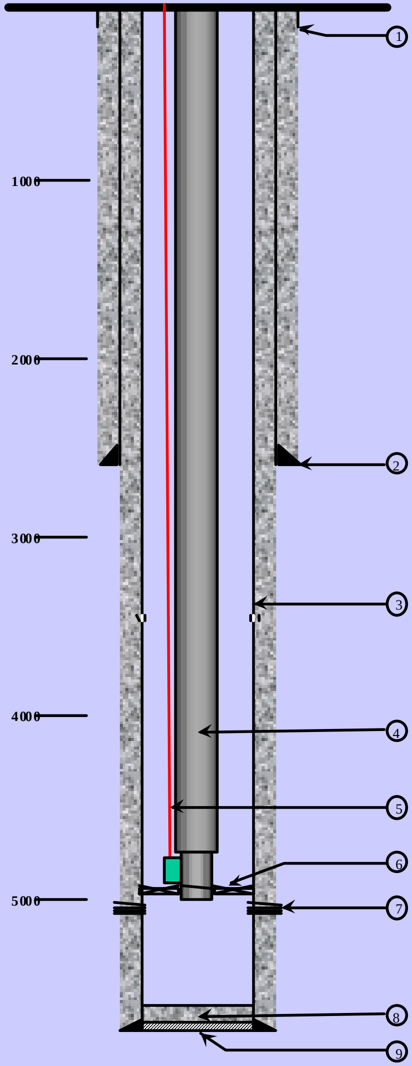
COMPLETION DETAIL

1. Conductor Pipe:
2. Surface Casing: 10-3/4" Set from surface to 2,040' (1952).
3. Protection Casing: 5-1/2" Set from surface to 8,964' (1952).
4. Squeeze Perforations:
   - 4,831' to 4,835' and 4,882' to 4,885'
   - 4,932' to 4,935' and 4,998' to 5,002'
   - 5,040' to 5,044' and 5,023 to 5,025'
   - 5,102 to 5,106' and 5,054' to 5,057'
   - 5,189' to 5,192' and 5,110' to 5,113'
5. Tubing String: Surface to 4,971'
   - 2-7/8" tubing Surface to 1,516'
   - Gas Lift Sub, 2-3/8" pup joint, 1, 516' to 1,521'
   - 2-7/8" tubing, 1,521' to 4,948'
   - Pressure Gauge Sub, 2-3/8" pup joint 4,948'-54'
   - Cross-Over Mandrel, 2" NU X 2-3/8", 4,954' to 4,960' (mandrel carries Sample Tube, Y and Check Valve, and Inflate Tube for Packer).
   - Inflatable Packer, Baker, w/3/8" pass-through SS line (sampler)
   - Inlet filter for Sample Tube
   - Wireline Re-entry Guide
6. Production Perforations: 5,014' to 5,034' w/ 4 shots per foot, 90 degrees phasing, 6.5 gram HMX charges, .245" entry holes, and 20" penetration. (8//2004)
7. Cast Iron Bridge Plug: 5,180' (8//2004)
8. Cement Plug: 6,129' to 6,327' (8/01/2003). Class H, 23 sacks.
9. Drilling Mud Plug: 6,327' to 7,931' (8/01/2003). 10.6-ppg.
10. Cement Plug: 7,931' to 8,414'(7/31/2003). Class H, 57 sacks.
11. Abandoned Perforated: 8,489' to 8,501' (7/31/2003).
12. Plug Back Total Depth: 8,600'
13. Abandoned Perforation: 8,810' to 8,914'
14. Total Depth Drilled: 9,516'

Installation of a New Injection Well

- Allowed for a detailed characterization of the Frio C Injection Sand (whole core and geophysical logs)
- Ensured a “high-quality” cement bond across the Frio Test Interval, Anahuac Shale, and protection of usuable sources of drinking water
- Costs of well installation were largely offset by reduced CO_2 volume and pumping time required for the experiment

New Injection Well Completion Detail



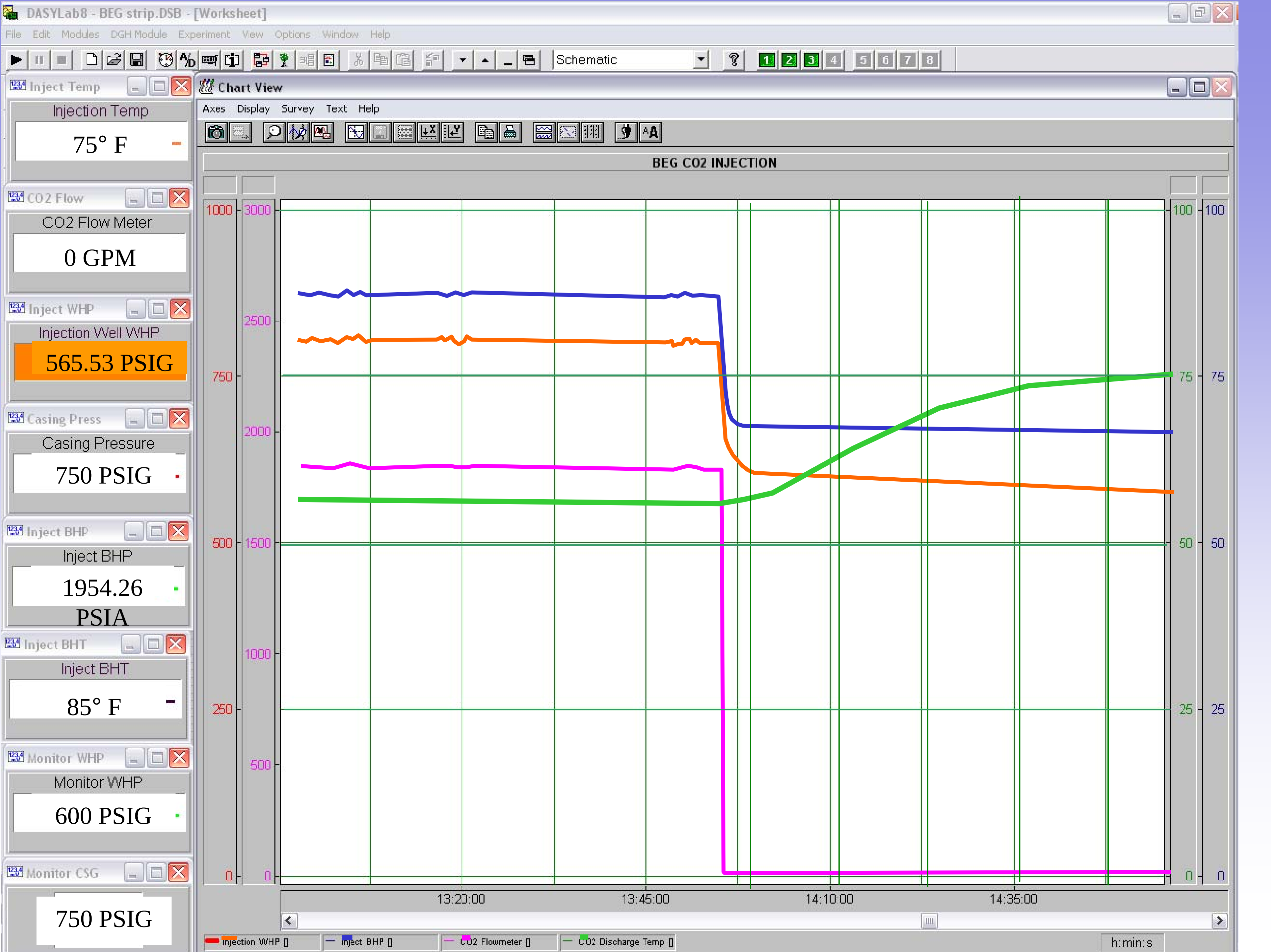
GROUND LEVEL = 65 ft Above MSL
RKB is 15.1' Above LMF

COMPLETION DETAIL

1) Conductor: 14" A-36, welded. Driven to +/- 118'.
2) Surface Casing: 9-5/8" 36-ppf J-55, EUE 8rd, ST&C. Set from surface to 2,668' in a 12-1/4" hole. Cemented with: 610 sks Lead Cement Class "A" 15:85 Poz Cement w/8% bentonite, + 3% salt at 12.4 ppg, and 270 sks Tail Cement Class "A" w/0.2% R-3 + 0.005 gps FP-6L at 15.6 ppg. Topped out with 12 bbls Class A w/2% CaCl.
3) Protective Casing: 5-1/2" 15.50 ppf, J-55, LT&C. Set from surface to 5,745' in a 7-7/8" hole. DV tool set at +/-3,653-55'. Stage 1; Lead Cement - 206 sks Class "H" 35:65 Poz Cement w/6% bentonite + 3% salt at 12.7 ppg. & Tail Cement 361 sks Class "H" w/10% NaCl at 16.4ppg. Stage 2; Lead Cement - 361 sks Class "A" 15:85 Poz Cement w/8% bentonite + 3% NaCl at 12.4 ppg. & Tail Cement 352 sks Class "H" Cement w/2% NaCl at 16.4ppg.
4) Injection Tubing: 2-7/8", 6.5 ppf N-80 EUE 8rd. Surface to 4,880', with X-over 2-7/8" X 2-3/8" N-80 EUE 8rd, Pup-Joint/Pressure Transducer Mandrel 2-3/8" N-80 EUE 8rd 4,880' to 4889'.
5) Wireline: Externally strapped to injection tubing, Surface to Panex 1320 pressure transducer attached externally with port at 4,886'.
6) Packer: Baker Hughes Hornet Mechanical Packer, 2-7/8" X 5-1/2", set at 4,889' to 4,897'
7) Production Perforations: Frio C Sand, 5,055' to 5,073' Owen Oil Tools, w/4 spf, 90 deg phase, 6.5 gram HMX charges, 0.245" entry holes and 20" penetration
8) PBTD: 5,634'
9) TD: 5,755'

Real-Time Data Acquisition System

- TCEQ Permit required continuous monitoring/recording of surface injection pressure, annulus pressure, injection rate, and injection volume
- The ASPEN Data Acquisition System allowed continuous monitoring/recording of:
  - Injection Well -> surface parameters - injection pressure, annulus pressure, injection rate, and injection temperature, and downhole parameters - pressure and temperature (Panex gauge just above the packer)
  - Observation Well -> surface parameters- pressure, annulus pressure, and temperature, and downhole parameters - pressure and temperature (Panex gauge just above the packer), and inflatable packer pressure


DASYLab8 - BEG strip.DSB - [Worksheet]
File Edit Modules DGH Module Experiment View Options Window Help
Schematic
Inject Temp
Injection Temp
75° F
CO2 Flow
CO2 Flow Meter
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Injection Well WHP
565.53 PSIG
Casing Press
Casing Pressure
750 PSIG
Inject BHP
Inject BHP
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PSIA
Inject BHT
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600 PSIG
Monitor CSG
750 PSIG
Chart View
Axes Display Survey Text Help
BEG CO2 INJECTION
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3000 2500 2000 1500 1000 500 0
100 75 50 25 0
100 75 50 25 0
13:20:00 13:45:00 14:10:00 14:35:00
Injection WHP
Inject BHP
CO2 Flowmeter
CO2 Discharge Temp
h:min:s

Real-Time Data Acquisition System - Continued

- The database was tied into a custom display package that allowed plotting of data and download of data during the experiment, without interrupting the data stream
- A web-based server location was set up to allow offsite “users” to access the plotting and downloading features so that experiment progress could be monitored from the office
- Real-time monitoring of surface and downhole conditions allowed Field Supervision to manage risk.

Summary

- The sequencing of experiments could be effectively managed to maximize scientific return within timing, budget, cross-test "interference", and borehole constraints
- Addition of a new injection well to the project scope allowed more detailed site characterization, increased confidence of permitting, and ensured containment of injected CO_2
- The Frio Brine Pilot provides the "stepping stone" for larger, up-scaled demonstration projects